7 F f

# A
# COPPER PLATE
# AND
# DISCOURSE
# OF THE
# TRANSIT OF VENUS,

On the 3d of JUNE 1769.

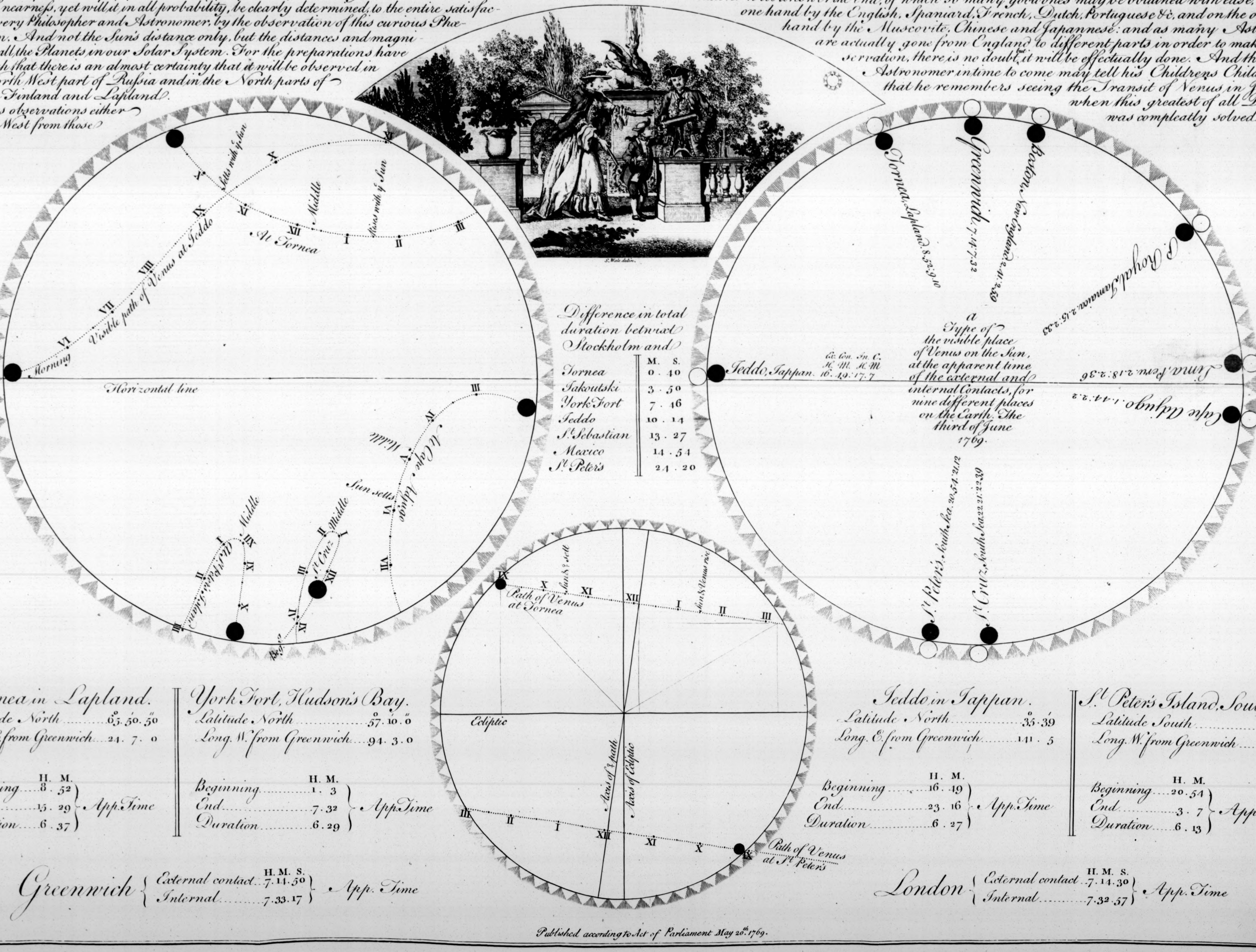
MOST HUMBLY INSCRIBED TO
HIS ROYAL HIGHNESS
**GEORGE**
PRINCE OF WALES.

MVSEVM
BRITAN
NICVM

# *Transit of Venus before the Sun 3d June 1769.*

## *The only one that will be seen by any of the human Race before the expiration of 105 Years.*

*The distance of the Sun from our Earth, tho' at present absolutely unknown within certain limits of nearneſs, yet will it in all probability, be clearly determined, to the entire satisfaction of every Philosopher and Astronomer, by the observation of this curious Phænomenon. And not the Sun's distance only, but the distances and magnitudes of all the Planets in our Solar System. For the preparations have been such that there is an almost certainty that it will be observed in the North West part of Ruſsia and in the North parts of Sweden Finland and Lapland. And as observations either East or West from those stations will answer the end, of which so many good ones may be obtained with ease, on the one hand by the English, Spaniard, French, Dutch, Portuguese &c. and on the other hand by the Muscovite, Chinese and Japannese: and as many Astronomers are actually gone from England to different parts in order to make the observation, there is no doubt, but it will be effectually done. And the Young Astronomer in time to come may tell his Childrens Children, that he remembers seeing the Transit of Venus in June 1769 when this greatest of all Problems was compleatly solved.*


S. Wale delin.
Morning
Visible path of Venus at Jeddo
Setts with ye Sun
Middle
Rises with ye Sun
At Tornea
Horizontal line
At Cape Adjugo
Middle
Sun setts
St Cruz
Middle
At St Peter's Island
Middle
Beg.
Tornea, Lapland 8.52:9.10
Greenwich 7.14:7.32
Boston, New England 2.41:2.59
P. Royal, Jamaica 2.15:2.33
Lima, Peru 2.18:2.36
Cape Adjugo 1.44:2.2
Jeddo, Jappan.
Ex. Con. In. C.
H. M. H. M.
16. 49:17.7
St Peter's, South Sea. 20.54:21.12
St Cruz, South Sea 22.21:22.39
a Type of the visible place of Venus on the Sun, at the apparent time of the external and internal Contacts, for nine different places on the Earth. The third of June 1769.
Sun's setts
Sun & Venus rise
Path of Venus at Tornea
Ecliptic
Axis of ♀ path
Axis of Ecliptic
Path of Venus at St Peters

*Difference in total duration betwixt Stockholm and*

| | M. | S. |
|---|---|---|
| Tornea | 0 | 40 |
| Jakoutski | 3 | 50 |
| York Fort | 7 | 46 |
| Jeddo | 10 | 14 |
| St Sebastian | 13 | 27 |
| Mexico | 14 | 54 |
| St Peter's | 24 | 20 |

### *Tornea in Lapland.*

Latitude North ........ 65°. 50'. 50"
Long. E. from Greenwich ... 24. 7. 0

| | H. | M. | |
|---|---|---|---|
| Beginning | 8 | 52 | App. Time |
| End | 15 | 29 | |
| Duration | 6 | 37 | |

### *York Fort, Hudson's Bay.*

Latitude North ........ 57°. 10'. 0"
Long. W. from Greenwich ... 94. 3. 0

| | H. | M. | |
|---|---|---|---|
| Beginning | 1 | 3 | App. Time |
| End | 7 | 32 | |
| Duration | 6 | 29 | |

### *Jeddo in Jappan.*

Latitude North ........ 35°. 39'
Long. E. from Greenwich ... 141. 5

| | H. | M. | |
|---|---|---|---|
| Beginning | 16 | 49 | App. Time |
| End | 23 | 16 | |
| Duration | 6 | 27 | |

### *St Peter's Island, South Sea.*

Latitude South ........ 22°. 0'
Long. W. from Greenwich ... 159. 30

| | H. | M. | |
|---|---|---|---|
| Beginning | 20 | 54 | App. Time |
| End | 3 | 7 | |
| Duration | 6 | 13 | |

| Greenwich | | H. | M. | S. | |
|---|---|---|---|---|---|
| | External contact | 7 | 14 | 50 | App. Time |
| | Internal | 7 | 33 | 17 | |

| London | | H. | M. | S. | |
|---|---|---|---|---|---|
| | External contact | 7 | 14 | 30 | App. Time |
| | Internal | 7 | 32 | 57 | |

*Published according to Act of Parliament May 20th. 1769.*

J. Mynde sculp.

# Of the DISTANCE of the SUN from our EARTH, and the Probability that it will be correctly aſcertained by Obſervations of the enſuing TRANSIT of VENUS.

AN endeavour to demonſtrate the magnitudes and diſtances of the Sun and other heavenly bodies, is ſo amazingly grand and pleaſing in the very Idea, and ſo intereſting in its conſequences, that it muſt neceſſarily raiſe the attention of every intelligent and conſiderate perſon. There is the higheſt probability that this grand problem, which has in vain been long and diligently ſought after, by many learned and ingenious men, will at length be decided, to the entire ſatisfaction of every Philoſopher and Aſtronomer. For a Tranſit of Venus before the Sun is the only cœleſtial obſervation, that can poſſibly give us full ſatisfaction in this matter: And the approaching one, is ſo peculiarly favourably circumſtanced, as almoſt to aſſure us of ſucceſs in this great and important point All other obſervations, though taken with the greateſt accuracy, and repeated ever ſo often, will ſtill continue to be found ineffectual.

FREQUENT obſervations of the Solar and Lunar eclipſes, and of the appulſes and occultations of the planets and fixed Stars by the Moon, will indeed determine the Moon's diſtance to a great degree of preciſion; eſpecially ſince the accurate tables of the celebrated late Mr. Profeſſor Meyer of Gottengen have been publiſhed: ſo that there is almoſt as much certainty of the diſtance of the Moon from our Earth by obſervations of the effects of parallax, as there is of the length of a piece of cloth, by being meaſured by the yard. But the ſame obſervations will not give us the ſun's diſtance, excepting within certain limits of nearneſs; beyond which, if we wander, we may be very erroneous. The diſtance of the Sun from our Earth is faſhionably held at about a hundred millions of miles yet it is abſolutely unknown, within much ſmaller limits of nearneſs; *i. e.* it cannot be much leſs than 40 millions, may probably enough be 40 millions more, and very poſſibly 400 millions.

For all aſtronomical calculations, except that of a Tranſit of Venus, would agree nearly as well with obſervation if the Sun's diſtance ſhould be only 40 millions of miles, as if it ſhould prove almoſt infinite: and the remarkable difference in opinion of the beſt Aſtronomers concerning the Sun's diſtance, is an evident proof of the above aſſertion. The celebrated late Mr. Profeſſor Meyer, when he made his Lunar tables, for many years thought the Sun's diſtance to be about 63 millions of miles, whereas, in the latter part of his time, he was convinced, as he thought, that it muſt be above 100 millions. The greater the Sun's diſtance is, the greater error in diſtance will there conſequently be with a ſmall error in parallax; Thus ſuppoſing the Sun's real diſtance to be 40 millions of miles, an error in parallax: of one ſecond would make an error in his diſtance of 2 millions of miles; but if his real diſtance is 137 millions according to De la Hire, an error in parallax of one ſecond would make an error in his diſtance of 20 millions.

The Sun's diſtance held by

| | | |
|---|---|---|
| Ptolemy, Copernicus and Tycho, about | 4¼ | Millions. |
| Bullialdus, | 5½ | |
| Kepler, | 13 | |
| Hevelius, | 19¼ | |
| Ricciolus and Horrocks, | 26 | |
| Newton and Caſſini, | 86 | |
| De la Hire, | 137 | |

And though this great difference amongſt aſtronomers has perhaps been one cauſe of the many fooliſh and odd conceits which have been publiſhed from time to time by the unſkilful in Aſtronomy, concerning the dimenſions of our Solar Syſtem, yet to thoſe who underſtand it the beſt, the gradual increaſe of the Sun's diſtance being not more remarkable than the improvements made in Aſtronomical calculations, is a ſtrong proof of the Sun's very great diſtance from us.

The quantity and effect of parallax decreaſes as the Sun's diſtance increaſes, and the contrary, it is therefore much to be admired, that ſince the time that the Sun's parallax was evidently found to be within one Minute, or his diſtance about 14 millions of Miles, that ſtill further improvements were made by the ingenuity and diligence of ſucceeding Aſtronomers. Particularly that the moſt accurate Lunar Tables of Mr. Profeſſor Meyer aforeſaid, will almoſt demonſtrate that the Sun's diſtance cannot be leſs than 60 millions of Miles; yet becauſe obſervation will ſometimes contradict, I have put the limits on the one hand to 40 millions and leſs than that it is ſuppoſed is impoſſible; becauſe, in that caſe, events would contradict calculations in numberleſs inſtances, ſo remarkably accompanying the infinite variety of affections of parallax, that it muſt be concluded it was owing thereto. On the other hand to 90 millions, beyond which if we go no obſervation of the Moon can give us any aſſiſtance. So that the Sun's diſtance held by Newton, Caſſini, and De la Hire, though differing from one another above 50 millions of Miles, is to any aſtronomical calculation except a Tranſit of Venus the ſame thing.

As to the antient Aſtronomers, who made the Sun's diſtance ſo ſmall, the conſequent events of their predictions were equally erroneous; and if the ſame diſtance was to be adopted now, of many Solar and Lunar eclipſes that it is certain will happen and be very near in their ſeveral circumſtances to calculation; ſome would not be to be found at all; the Moon's place being either too high or too low, too much eaſt or too much weſt; and others which would be found by calculation, would greatly differ both in time and quantity from the truth.

The Moon's motion is too quick; and her parallax much too great for the purpoſe, being in the Horizon at a mean rate near a degree: upon which account, though it is the moſt deciſive proof in the World of its own mean diſtance from us, viz. about 240 thouſand Miles, yet for this purpoſe it is quite unfit.

I have obſerved ſeveral eclipſes, appulſes, and occultations, the times and other circumſtances of which have agreed to a ſurprizing degree of exactneſs with my own calculations beforehand; and have now by me, calculations of moſt, if not all the Solar and Lunar eclipſes, that will be viſible at Greenwich, from the preſent year 1769, to the year 1780; which there is not the leaſt doubt will prove in the times and quantity eclipſed, as near to calculation as thoſe which have been obſerved before: and ſhall mention as a pretty remarkable circumſtance, that a late Author having publiſhed the Types of all the viſible eclipſes till the year 1800, and the times of the contacts, upon a compariſon of ten, viz. four Solar and ſix Lunar, there is but one that differs ſo much as 4 M. 50 S. in the time of whole duration and but 5 M. 20 S. in time of either contact; and ſeveral of them come within one minute of whole duration; which is an agreement ſo near, that a difference of latitude of the Moon of ſcarce 15 S, would in many caſes effect: ſo that the Moon's diſtance from the Earth is well aſcertained, and that with ſuch force of proof, when we conſider that through an almoſt infinite variety of affections of parallax the appearance does almoſt invariably accompany thoſe affections, and to ſuch a degree of preciſion, that it may be pronounced that the mean diſtance of the Moon, from this Earth, is about 240 thouſand miles: yet this is not to be underſtood ſo accurately as that there cannot be an error of a 200th part of the whole, but it is much more probable that there is not an error of a 300 part; under which limits I would have the foregoing aſſertions concerning the diſtance of the Moon to be underſtood: and theſe events always follow calculation, when the ſum of the parallaxes of the Sun and Moon is uſed, and when the difference of parallax is uſed, and when the Moon's parallax is uſed by itſelf.

The mean quantity of the Moon's Horizontal parallax is about twice her diameter; then if we conſider the phaſes of one particular Solar eclipſe, we ſay that in one part of the Earth the Moon will juſt touch the upper limb of the Sun, in another part the under limb, in another the eaſtern edge, in another the weſtern edge, in one part it will be of the ſmalleſt duration in time, in another part of longer duration, in another part central and of the longeſt duration of all; and in all the varieties of directions and quantities that you can ſuppoſe two ſpheres to be put before each other, which varieties though almoſt infinite, are owing to parallax, and always invariably follow the quantity and affection of parallax calculated for any particular place at any given time. The ſame may be ſaid of different eclipſes in the ſame place; and this whether the Sun's diſtance from us be 60 millions of Miles, or 600 millions. Wherefore, the diſtance of the Moon from us is as well aſcertained, as the ſemidiameter of the Earth, upon which it entirely depends; and that is as certainly known as the Statute meaſurement of Miles betwixt London and Edinburgh, or betwixt Greenwich and Upſal. The forementioned calculations were made on a ſuppoſition of the Sun's diſtance, being about 90 millions of Miles, or its horizontal parallax about 9 ſeconds, according to the preſent faſhion, yet had the Sun's horizontal parallax on the one hand been aſſumed as large as 14 ſeconds, and its conſequent diſtance not 60 millions of Miles; or on the other hand had it been aſſumed ſo ſmall as 4 ſeconds, and its conſequent diſtance above 200 millions, the reſult I ſay of the calculations would have been very nearly the ſame, ſo near both in quantity eclipſed and time of duration, that if the difference could poſſibly be obſerved, yet the cauſe muſt remain a ſecret.

SINCE then this great Problem ſeems not capable of being anſwered to ſatisfaction by any other cœleſtial obſervation than that of a tranſit of Venus, let us apply to the approaching one with all diligence, both becauſe it is the only one that the preſent race of men will ever have in their power to obſerve, and alſo becauſe it is every way ſuited for the making ſuch diſcovery. The particular motion of Venus in her orb, her relative diſtance from the ſun, and the diſtinctneſs and clearneſs by which the times of the contacts may be determined, are ſo well adapted for the purpoſe that it cannot ſufficiently be admired; for ſhe will be above 18 minutes of time in paſſing over an arch of leſs than one minute, ſo that there will be full 18 ſeconds of time for 1 ſecond of motion, and the contacts will be ſo well defined, that the times of them may be determined by a common obſerver to a few ſeconds, yea, ſo very diſtinctly, that with a little caution none can materially err.

I SHALL mention one caution, which the reader, no doubt, will agree to on the firſt reflexion, viz. that an impreſſion cannot be made but the time of the contact muſt be ſome few moments elapſed, which is always allowed for by aſtronomers, and that the more truely, as the perſon is more accuſtomed to obſerving and the more accurate. This being premized, there is no doubt but there would be an agreement to a few ſeconds in time of contact, if a thouſand perſons were to obſerve it in the ſame place, and by clocks exactly agreeing with one another. In the year 1761, very many in England, and ſome particularly in Lancaſhire, quite unaccuſtomed to aſtronomical obſervations, determined the time of the egreſs to be the ſame, to a few ſeconds, with the obſervers at Greenwich. And though it is probable, that Venus has an atmoſphere, yet is it ſo very tranſparent, that it is not the leaſt hinderance to the ſight of the very moment of contact. There was a very great brightneſs round the planet ſome moments after the laſt contact in 1761, and that ſo diſtinct and brilliant, as to aſſure me that a ſpherical body was there, whoſe ſide from me was illuminated. As the time of the contacts can ſo eaſily and accurately be obtained; and as the effect of parallax in Great Britain and Ireland, at the firſt external and internal contacts is almoſt a maximum; and there being innumerable places on the earth where the firſt contact will be ſeen, and where the effect of parallax will be greatly diminiſhed, it is ſcarcely poſſible, but that this method will determine this problem to a conſiderable degree of accuracy. For all along the ſea coaſts, and in all the great towns of New England, New York, Virginia, Maryland, Pennſylvania, and Carolina, there will be a difference in time of the firſt contact from Greenwich on account of parallax of 2½ minutes to 3½ minutes; the ſame of York Fort, and all along the coaſt of Hudſon's Bay; Jamaica and the Iſlands adjacent 4 minutes; the coaſt of America, St. Sebaſtian, Lima, and Adjugo 6 minutes to 6½; Mexico, Compoſtella, and towns adjacent 6 minutes; St. Peter's, St. Cruz, and other Iſlands in the South Sea, about 12 minutes. Eaſtward from us, in the Ruſſian Empire, about Jakoutſkie from 2 to 3 minutes; all along the eaſtern coaſt of the continent, from 45 to 60 degrees of north latitude, and 140 to 142 degrees eaſt longitude, 5 to 6 minutes, and in Japan 7 minutes.

AND when it is farther conſidered, that the laſt contact may be as eaſily obtained at Tornea, Wardhuys, and places adjacent, where ſeveral aſtronomers are gone on purpoſe to obſerve, as the firſt contact can in Great Britain: and the effect of parallax in thoſe places, and all the north weſt parts of Ruſſia, is almoſt a maximum in lengthning the time; and that the places upon earth where the effect of parallax, at the laſt contact, will be greatly diminiſhed, are as numerous as for the firſt contact, and even ſome places where the affection will be quite changed. I ſay, this being conſidered, it is hardly poſſible but the ſun's parallax muſt be accurately determined by ſuch a very great variety of affections and effects of parallax.

THUS much for thoſe places where only one contact can be obſerved. But above all it becomes in the higheſt degree probable, in that there are many places where the whole duration can be obſerved.

FOR in this caſe, neither a nicety in the latitude or longitude of the places, nor in fixing a meridian line, nor the uſe of a true eccentricity of the earth or Venus's orbit, are at all neceſſary as they are in the former. And though theſe ſeem to be difficulties, in the firſt method, yet by the very great number of places where the contacts will be ſeen, and by the unſpeakably curious adjuſtment of Venus's motion for the purpoſe, they can, with eaſe, be overcome; inſomuch, that not only the ſun's parallax, but even the longitudes and latitudes of the places might be thence truly determined though there was no other method.

BUT that is not the caſe, for there are a great many places where the whole duration may be taken as was before ſaid; and where, for the reaſons above mentioned, that circumſtance only needs to be attended to. Since then the total duration may ſo eaſily be obtained, let us examine what effect a ſmall error in time (we will ſay ſix ſeconds) will have upon the ſun's parallax, admitting his diſtance to be about 90 millions.

THE anſwer is plain, that in ſome parts of the earth compared with others, as the total duration in Tornea compared with the total duration in the South Sea, ſuch an error in time would cauſe a correſpondent error in the ſun's parallax, of not ſo much as the twentyninth part of a ſecond. The ſame error of time in the obſervation at Tornea, compared with one about Mexico or Compoſtella, would make an error in the ſun's parallax of about $\frac{1}{18}$th part of a ſecond, compared with one at St. Sebaſtian $\frac{1}{16}$th part of a ſecond, all along the north eaſt coaſt of Ruſſia and north part of Japan $\frac{1}{13}$th part of a ſecond, York Fort $\frac{1}{10}$th part of a ſecond, Jakoutſkie $\frac{1}{6}$th part of a ſecond; and this is a degree of preciſion that muſt be highly ſatisfactory to every philoſopher and aſtronomer.

BUT if ſome caution be uſed beforehand, and every reaſonable allowance granted for one as for another after the obſervation, I am perſuaded there need be no ſuch error.

YET, I ſay, ſhould ſuch an error happen, it muſt ſtill give the higheſt ſatisfaction, as the beſt aſtronomers in the preceding, and preſent age, have diſagreed in the quantity of the ſun's horizontal parallax, 30 or 40 times as much as the above; ſome making it little above 6 ſeconds, others 7, 8, 9, 10. 12. 15. to 20. and with this remarkable circumſtance of there being no likelihood of ever having ſatisfaction in this point, but by an obſervation of the tranſit of Venus. The particular motion of Venus, and its relative diſtance from the ſun, are ſo very nicely adapted for finding out the ſun's parallax, that they almoſt ſeem to be given for that very purpoſe; and it would, hereafter, have been accounted worſe than ſtupidity, if the preſent generation of men ſhould have neglected this only opportunity of obſerving it.

HAD Mercury's apparent diameter been as large as Venus's, and the contacts as diſtinctly to be ſeen; yet, becauſe of its particular diſtance relative to the ſun's diſtance, the difference of horizontal parallax of Mercury from the ſun, will be five times as ſmall as that of Venus's from the ſun, and the quantity of time will be ſtill more diminiſhed by the quicker motion of Mercury, which will render any obſervation from thence, either very uncertain, or quite uſeleſs for the purpoſe; neither is there any other cœleſtial obſervation known that can give us the leaſt ſatisfaction in this great and important problem.

We have ſaid before, that there will be full 18 ſeconds of time for one ſecond of motion, and that the contacts will be ſo well defined, that none need materially to err: wherefore, though it will be fruitleſs to attempt to determine the ſun's diſtance by obſervations made at a few places near one another, yet, for the very ſame reaſon, it will be the moſt deciſive thing in the world at ſuch diſtances where the different effect of parallax will be tolerably great.

In the year 1761 the greateſt difference of duration betwixt the contacts at four different places, viz. Stockholm, Hernoſand, Abo, and Tornea, by very eminent obſervers, was only 51 ſeconds of time, and the difference of whole duration 47 ſeconds. The ſame may be ſaid of the obſervation at Upſal, which, in duration betwixt the contacts agreed with the others, but in the duration of ingreſs there ſeems to be a miſtake, for it differs near a minute from all the reſt, and from other parts of the ſame obſervation; viz. the time of the egreſs; wherefore we may ſafely conclude, that the firſt contact was not diſtinctly ſeen. Theſe and other obſervations at Tobolſk, Cajaneburgh, and Fort St. George in the Eaſt Indies, are all that I know of where the whole duration was obſerved in 1761. I made a calculation for ſix of the places on a ſuppoſition that the ſun's horizontal parallax was 9 ſeconds; yet, it would have done as well, I am perſuaded, if the ſun's horizontal parallax had been aſſumed two thirds as much more; for though the calculated times came ſo very near the obſerved times, as not, in any caſe, to differ ſo much as one minute, yet the differences did not follow parallax, but indeed, ſeemed rather to warrant a larger parallax. At Madraſs I was in hopes ſomething might have been diſcovered, but, upon calculation, though the affections of parallax at the contacts were different from any of the reſt, yet the effect thereof, as to duration, was ſo near the reſt, that no true concluſion could be drawn therefrom; neither could there be, though 500 tranſits ſhould be obſerved under the ſame circumſtances, *i. e.* at places either very near one another, or even at great diſtances, where the effect of parallax would be the ſame.

It will perhaps, be acceptable to ſome, to have the obſerved times of the contacts and duration at the places abovementioned, wherefore take them as I have them.

| | Beginning. | | | End. | | | Duration. | | |
|---|---|---|---|---|---|---|---|---|---|
| | H. | M. | S. | H. | M. | S. | H. | M. | S. |
| Stockholm, by Monſ. Wargentein —— | 15 | 21 | 37 | 21 | 48 | 6 | 6 | 26 | 29 |
| Tornea, by Meſſ. Lagerburn and Hallant | 15 | 45 | 47 | 22 | 12 | 20 | 6 | 26 | 33 |
| Abo, by Monſ. Juſtander — — | 15 | 37 | 51 | 22 | 4 | 42 | 6 | 26 | 51 |
| Hernoſand, by Meſſ. Giſtor and Strom — | 15 | 20 | 40 | 21 | 46 | 44 | 6 | 26 | 4 |
| Upſal, by Meſſ. Mallet, Stromer, and Bergman | 15 | 20 | 9 | 21 | 46 | 23 | 6 | 26 | 14 |
| Madraſs — — — | 19 | 31 | 10 | 1 | 55 | 44 | 6 | 24 | 34 |

I shall remark, that the beginning at Upſal was given me 15 H. 20 M. 45 S. which is 36 ſeconds later than is put down, and is my own alteration, as I am perſuaded it muſt be a miſtake. In the foregoing obſervation, it is worth notice, yet no wonder at all, that the times of whole duration agree ſo very near, but that the times of the contacts ſhould agree ſo accurately with the longitudes and latitudes of the places is ſomewhat extraordinary, unleſs the longitudes and latitudes of the places were taken from that very obſervation' than which a better would not be deſired for the purpoſe. So alſo, in the approaching tranſit, when it ſhall have been obſerved in the north parts of Denmark, Sweden, and Lapland, and in the north weſt parts of Ruſſia, we ſhall find an agreement in the total duration within certain very ſmall limits, as we did in the year 1761. Yet if we had no other diſtant place to compare with them, we ſhould be never the nearer with regard to determining the Sun's parallax, and conſequently its diſtance, than if no ſuch obſervation ever had been; and we are yet in the greateſt uncertainty about it, notwithſtanding the tranſit in 1761. But had the total duration then been obſerved on any part of the Earth where the effect of parallax would have been ſo circumſtanced as to have made the viſible duration conſiderably longer than it was in Lapland and Sweden, I am perſuaded the Sun's parallax and diſtance would then have been determined to a conſiderable degree of preciſion; much more ſo if it had been obſerved where the viſible duration would have approached any thing near to a maximum. But as this was not the caſe, though I believe it was prevented by unavoidable accidents, let us attend with all diligence to the enſuing one, which is ſo much more favourably circumſtanced both with regard to the much greater number of places where the total duration may be conveniently obſerved, and alſo with regard to the almoſt infinite number of places where the contacts may be ſeen: in both of which caſes there will be a much greater effect of parallax by reaſon of the Planet's greater Latitude. Let us ſuppoſe the tranſit to have happened and that the total duration was obſerved to be at

| | H. | M. | S. | | H. | M. | S. |
|---|---|---|---|---|---|---|---|
| Stockholm | 6 | 36 | 42 | Mexico | 6 | 21 | 24 |
| Upſal | 6 | 36 | 40 | Compoſtella | 6 | 21 | 18 |
| Abo | 6 | 36 | 37 | Tompeck | 6 | 21 | 0 |
| Hernoſand | 6 | 36 | 37 | | 6 | 20 | 50 |
| Tornea | 6 | 36 | 1 | | 6 | 20 | 38 |
| Port Nelſon | 6 | 29 | 20 | St. Peter's Iſland | 6 | 12 | 47 |
| Cape Churchill | 6 | 29 | 25 | Fly Ditto | 6 | 11 | 40 |
| New Severn | 6 | 29 | 9 | Amſterdam Ditto | 6 | 11 | 34 |
| Cape Southampton | 6 | 28 | 59 | St. Cruz | 6 | 11 | 22 |
| Nottingham Iſle | 6 | 28 | 32 | Mendoza | 6 | 11 | 1 |

I ſay ſuppoſe it had been obſerved, and that theſe differences in total duration from Tornea or any of the places not far diſtant from it had been found, which differences in total duration from Tornea will undoubtedly happen if the Sun's horizontal parallax is nine ſeconds, let the total duration at Tornea be what it will.

Would not then the differences of ſome good Aſtronomers concerning the Sun's diſtance be reduced to very narrow bounds; and would not the faſhionable agreement of other good Aſtronomers that the Sun's diſtance is about one hundred Millions of Miles, be either confirmed beyond a poſſibility of contradiction, or demonſtrably proved to be erroneous? and would not all Aſtronomers univerſally agree in the Sun's diſtance within very ſmall limits as they would in the moſt ſelf evident truth, or any mathematical demonſtration?

It is a peculiarly favourable circumſtance in this method of obſervation, viz. of the total duration, that a nicety in the longitude and latitude of the place is not at all neceſſary, for a difference of 2 or 3 degrees in latitude, and as much in longitude, will make very little alteration in the time of duration; as may be ſeen by a compariſon of the duration at Stockholm, Upſal, Abo, and Hernoſand, with Tornea, which lies 5 or 6 degrees north of moſt of them, and as many degrees eaſt; neither would it make much alteration if the ſun's horizontal parallax ſhould prove 12 or 14 ſeconds: but what a difference in time of total duration would there be in ſome parts of the earth, compared with others, if that were the caſe? To be ſure near 40 minutes!

If, on the other hand, the ſun's diſtance ſhould prove very great, we will ſuppoſe 4 ſeconds for parallax, then would its diſtance be above 200 millions of miles; I ſay, that in this caſe, the difference in total duration betwixt Tornea and York Fort will be about 4 minutes of time, Tornea and Mexico 8 minutes, and Tornea, and parts in the South Sea 12 minutes; and conſidering the caſe and clearneſs with which the contacts may be ſeen, even by perſons unaccuſtomed to aſtronomical obſervations; the proof of the ſun's diſtance to a great degree of preciſion will be indiſputable; nay, farther, it would be ſo if the ſun's diſtance ſhall prove 300 millions.

If the ſun's parallax ſhall be ſuppoſed as large as 13 or 14 ſeconds, there ought not to be a difference in time of total duration, on account of parallax of above 56 or 58 ſeconds in any two places upon earth, two or three degrees remote from each other in longitude or latitude, or both; yet, in ſome places of the earth which have been mentioned, there will be the remarkable difference of above 40 minutes with the ſame parallax.

The ſame may be ſaid proportionably of the times of each contact: In ſome places, even very diſtant from each other, the difference of time, on account of parallax, will be = 0; in others plus or minus a minute, two, three, four, five, up to twelve minutes; or if the ſun's parallax ſhould prove to be 13 or 14 ſeconds to 20 minutes. The places where one or other of the contacts can be ſeen are almoſt innumerable, and the obſervation of both contacts in the North Finland, Lapland, and Ruſſia; where the effect of parallax at each contact is almoſt a maximum, being almoſt as certain as if already paſt; and there being, moreover, very many places where the whole duration can be obtained, and the world duly apprized of it: there is, therefore, the greateſt degree of probability that it will be effectually done; and that the uncertainty of aſtronomers concerning the ſun's parallax, and conſeſequent diſtance and magnitude, will be finally removed, or ſomething new in theory diſcovered.

It may be of great uſe to obſerve carefully the contacts in England, Scotland, and Ireland; for the longitudes of the different places from London, may be better aſcertained by this ſingle obſervation, than by 20 eclipſes of Jupiter's firſt ſatellite; for in any county of Scotland, as far north as 56°, and in any of the eaſternmoſt or weſternmoſt parts of Ireland, there will not be a difference in time, on account of parallax of above 14 or 16 ſeconds; and in many counties of England, ſcarce any at all.

The Spaniard, of all other nations, has the advantage of eaſily obtaining obſervations upon land, at thoſe places where the duration will be very ſhort; for there is a great probability, that both internal contacts will be ſeen in the city of Mexico, and there are many other places north weſt of it, as Compoſtella, &c. where they undoubtedly may; and it will be better obſerving, as the ſun's altitude will be greater at the laſt contact; but eſpecially of ſending out ſhips from Acapulca, Lima, Panama, or ſome port on their coaſt to the iſlands in the South Sea, where the duration will be almoſt the ſhorteſt poſſible.

And becauſe a tranſit has happened ſo lately, and opened the eyes of all nations concerning the conſequence of making a good uſe of the preſent one; it is, therefore, not to be doubted, but the king of Spain has made preparations for obſerving this curious Phœnomenon. Certainly, if I was a Potentate, and had ſuch a good opportunity, and did not embrace it, I ſhould, afterwards, cry out with the emperor of Rome, *that I had loſt a day.*

But God be thanked, we have authentic accounts, that preparations for obſerving have been made in many parts of the earth. Particularly, that the empreſs queen of Ruſſia (it is ſaid) has ordered, that the tranſit be obſerved in 8 different parts of her empire. It muſt be great pleaſure to reflect, that her Imperial Majeſty has a fair probability of determining the moſt important problem in aſtronomy within the compaſs of her own extenſive dominions, as the difference in total duration betwixt the north weſt part and north eaſt will be very conſiderable, amounting to eleven minutes at leaſt; for, at Archangel, the viſible total duration will be nearly the ſame as at Tornea, Abo, &c. viz. 6 H. 36 M. &c. whereas, all along the eaſtern coaſt of the empire, from 50° north latitude, to 70° the viſible, total duration will amount to little more than 6 H. 25 M. according to the different ſtations of the obſervers.

It may be taken notice of here, that a ſtation 2 or 3 degrees north of Archangel, will be as good an one as any in the world, as the ſun's altitude, at each external contact, will be very favourable. We have alſo good accounts, that one ſhip at leaſt, of our moſt gracious Sovereign's, is gone to the South Sea, and another to York Fort, in either of which places the whole duration may be obſerved; and as the difference in time of the firſt contact is pretty conſiderable at the one place, and almoſt as great as poſſible at the other, there is, therefore, a great probability, that his Majeſty will be able to decide this moſt important point.

The ſtation at York Fort is more particularly a good one, to compare with the obſervations in Sweden, Finland, and Lapland: as at the firſt contact there will be a difference of near 3 minutes, at the laſt contact of above five minutes, and in whole duration, near 8 minutes on account of parallax.

And, becauſe one or other of the contacts may be ſeen in ſo many places in the world, viz. all along the coaſt of California, Mexico, and Peru, and upon land, in numberleſs places on thoſe coaſts: at Hiſpaniola, Jamaica, and all the Windward and Leeward Iſlands; all the ſea coaſts and inland towns in North America; all along the eaſtern ſide of Ruſſia, Japan, and China, and in moſt of the Ladrone Iſlands; there is, therefore, no room left to doubt of ſucceſs.

I shall mention one particular circumſtance with regard to a general inſtruction to the inhabitants of Great Britain and Ireland, for finding the firſt contact; and that is the very ſmall difference of azimuth of Venus and the ſun, which does not exceed 8 ſeconds; wherefore, the firſt contact will happen in the higheſt part of the ſun's limb, or that which is directly perpendicular to the horizon, or ſo near, that if a perſon's eye is fixed there, he cannot well fail of ſeeing the firſt impreſſion.

The calculations of this tranſit, though made with a good deal of care, have not had that pains taken with them that the ſubject will deſerve, when we ſhall have got our own and foreign obſervations. But yet, after finding the viſible hourly elongation, by the increaſe and decreaſe of parallax in longitude, and viſible neareſt approach of centers, and taking into the account, the increaſe and decrease of parallax in latitude; the time of each contact, given me by the ſolution of the triangles in the ſmall figure, (reckoning them either plain or ſpherical) agreed ſo well with the times of each contact, found by the difference of the ſun's and Venus's altitude and azimuth, as to give aſſurance they are very near the truth.

As to the difference in time of the firſt contact, found by aſtronomers for the ſame place, it is no objection to any thing that has been ſaid, but rather to be wondered at, conſidering ſo few opportunities that men have had, of obſerving a tranſit, that they ſhould agree to 12 or 14 minutes.

THE foregoing calculations were not made from any tables, but from a careful examination of an obſervation made by Mr. Horrocks, November 24, 1639. at Hoole, in Lancaſhire; (the firſt tranſit of Venus, perhaps, that was ever ſeen by any of the ſons of Adam) and the foreign obſervations, joined with my own, of the tranſit in 1761. Hence was determined the mean motion of Venus, her radical place, and place of her node; the equation of her centre, and her geocentric latitude; and theſe all true to a ſingle third. It was found in the proceſs, that if the angle of commutation had not been found to a ſingle third, the correſpondent error in elongation, would have been pretty large, if calculated for half an hour before and after the conjunction.

I HAVE taken no account of refraction, as it appears by the obſervation in 1761, that the effect thereof was not to be perceived, even in places where the ſun's altitude was very different, as in Lapland and Great Britain. Though the viſible place of Venus upon the ſun at the internal contact, will be infinitely various, according to the different ſtations of every obſerver upon earth, and her viſible path in all ſorts of curves and directions, occaſioned by the continual changing of the angle of the ecliptic with the horizon, as may be ſeen by the few examples in the two firſt figures of the plate; yet, with reſpect to the ecliptic, her motion and inclination will be conſtant and uniform, as in the ſmall figure of the plate, and this I have found by a calculation of the elongation and motion in latitude for ½ an hour, 1, 2, 3, 4. 8. and 24 hours before and after the conjunction.

AFTER a careful examination, whether a difference of 20 would affect the whole duration, I have fixed upon 505 for the eccentricity of her orbit.

FOR the eccentricity of the earth's orbit, I have kept as cloſe as poſſible to my own obſervation of eccentricity, and uſed my own ſolar tables. The viſible paths of Venus were taken from a calculation of the difference of the ſuns and Venus's altitude and azimuth at intervals of every half hour.

The Reader cannot be ignorant that the following may hereafter be of great uſe.

## Mr. Horrocks's Obſervation, 1639 November 24th.

OBSERVRAVI per Telleſcopiam conjunctionem Solis and Veneris nobiliſſimam, in obſcura camera. Diameter Veneris fuit 1' 10'' qualium Sol habet 30, certe on major.

VENUS intravit diſcum Solis ad ſiniſtram (ad dextram lege) gr. 62. 30. (certe inter 60 and 65°) a vertice. Fuitque eadem inclinatio conſtans uſque ad occaſum Solis.

Hoc intus in radio; contrarirum in cœlo apparuit; fuitque Venus inferior centro Solis ad ſiniſtram.

Horologium

| | H. | M. | Diſt. centrorum | M. | S. |
|---|---|---|---|---|---|
| Horologium | 3. | 15 | Scrupula | 14. | 25 |
| | 3. | 35 | qualium | 13. | 30 |
| | 3. | 45 | Sol 30. | 13. | 0 |

N. B. His equation of time
Suns Anom 0, 1, 2, 3, 4, 5.
Sub from App. maximum 7'. 56"
Sun's place ♈ ♎ ♉ ♏ ♊ ♐
Sub from App. maximum 9'. 55"

## SUN'S DIAMETER.

Solis diameter Lanſbergio eſt 36′ fere in Perigæo, Keplero 31′ tantum. Mirum profecto tantum diſſedere Aſtronomos! Æquo animo ferre debit Lanſbergius Tychonem 3 aut 4′ in Spicæ latitudine ab ipſo ac Ptolemæo differre, cum ipſe plus adhuc (ſcrup. 5) a Keplero diſſentiat in Solis diametro menſuranda. Ad hæc quam ſcrupuloſus ſit Lanſbergius mirari ſatis non poſſum. Semidiameter Solis, inquit, in Perigæo, eſt 17′ 59″; cur non 18 rotundo numero? Nimirum ille de ſecundi unici errore metuit, cum interim procul omni dubio certiſſimum eſt eum ſcrup. 4′ aut 5′ erraſſe.

Qua de re, ut certior evaderem, multos menſurandi modos tentavi, quorum nulli Solis diametrum ad 35′ 58″ imo neque ultro 31′ 30′ cum plurimum extendunt.

He then mentions ſome methods of meaſuring it; but never found it to exceed or ſcarcely come up to 30½ in ſummer, and 31½ in winter. In 1637, after many meaſurements of the Sun's diameter, he ſays, Concludendum itaque hinc videtur Solis diametrum in Apogæo 30½, in Perigæo 31½.

I shall remark on Mr. Horrocks's obſervation, that Venus's entrance on the Sun, betwixt 60 and 65° from the vertex, confines the viſible latitude of Venus at the central ingreſs to be betwixt 11 and 12 minutes, which of itſelf is a good obſervation; and he always diſtinguiſhes betwixt horologium and hora vera; ſo that his whole obſervation is clear and diſtinct, and worth being regiſtered in gold.

As to any true deduction of the Sun's parallax from the theory of gravity, it is held next to impoſſible, ſince there are a great many minute things whoſe quantities cannot be demonſtrated, and which are yet neceſſary to be known to the greateſt degree of preciſion; in order to the bringing out a true concluſion. As firſt, the preciſe quantity of the diſturbing force of the Sun upon the Moon at any given time, the proceſſion of the equinoctial points, the exact figure and quantity of our earth, &c. and others perhaps which we have no knowledge of at all. The ſmalleſt error in any one of theſe nice matters, and perhaps many others which ought to be taken in to the account, might on the one hand by calculation give the Sun's diſtance 2, 3, 4, or 5 times too ſmall, and on the other hand exceed as much.

This ſubject cannot be diſmiſſed without acquainting Aſtronomers of a table of the equation of time, got by a particular obſervation, and recommending the ſame method for further improvement.

When it was firſt began, there was a tin plate with a hole in it about ⅕ of an Inch diameter well faſtened with iron in a window that looked ſouth; the plate was about 4¼ feet from the ground; when the Sun's center was upon a meridian line on the floor, a pin was ſtuck on the eaſtern edge of the ſpeck of light; this was repeated ſeveral days, when another line was drawn through the points, which made an angle with the meridian line of about 15½ minutes, and both lines made as diſtinct as poſſible. When the window was quite darkened, the edge of the ſpeck of light, might be ſeen to toutch the outer line, to as fine a degree as need be, poſſibly with a little practice to a ſingle ſecond: the center of the ſpeck being ſtill upon the meridian line. If the tin plate is fixed ſo nigh, few rooms will be large enough for the line to be on the floor in Winter, but a perpendicular being let down on the oppoſite wall to the line on the floor it will be finiſhed. The next thing was to regulate the Clock, which was done by the diſappearance of ſtars beyond a ſtreight wall, or ehimney; the wall or chimney ought to be as near ſouth as poſſible, and at any diſtance from 20 to 80 yards, the time of the ſtars diſappearing may be determined accurately beyond diſcription.

The Clock was ſoon found to go exceeding well and I reſolved to keep an accurate account of the going of the Clock for one whole Year, as I could ſo diſtinctly ſee the Sun's coming to the meridian, and had this method of knowing how much the Clock was too faſt or too ſlow.

The experiment was begun on the twenty ninth of Auguſt 1763, when the mean and apparent time are very near together: after fixing the clock right, and during the obſervation, correcting each days variation, which I could eaſily and accurately do by the diſappearance of the Stars at the rate of 3,$'$ 55,$''$ 54,$'''$ 33,$''''$ 49,$'''''$ &c at the years end it gave me a table of the equation of time, differing but a few ſeconds in any part of it from the common equation table uſed. The clock had a ſpring to keep it going whilſt winding up, and was not altered one moment backwards or forwards the whole year.

At firſt begining, though it was but 10$''$ of time from the clock which was acroſs the room, and had candles ready fixed, yet I uſed a ſtop watch; but very ſoon found it needleſs. There were generally five or ſix Stars fixed, and when any one came too near the light, care was taken to transfer it to another. Their diſappearances were ſo eaſily and accurately to be taken, that many times there was no occaſion to repeat the obſervation in transferring, but was done at firſt to a ſingle ſecond of time: yea ſo very accurate were they, that I affirm, one winter's evening, from about five o' clock to twelve, had ſix obſervations of different Stars, at which time the clock was going too faſt nearly at the rate of 3$''$ per day, when I had finiſhed all ſix obſervations, and ſeen by each how much the clock was to faſt, which was done at firſt ſetting pen to paper, and allowing beforehand 1$''$ for the clock's being faſter at its laſt obſervation than the firſt, I ſay one ſecond, and affirm it, that they all agreed without a variation of one ſingle ſecond. The next day at noon, I went to the meridian line, and put down the time that the Sun came to it, always allowing for the clock from night to noon according to its then preſent going, and the general correction by the diſappearance of ſtars from the time it was firſt fixed. At the years end it gave a table of the equation of time not differing 8 ſeconds in any part of it, from one made of the difference of the Sun longitude and right aſcenſion, turned into time on the one part, and the equation of the center at an ecentricity of 1680 on the other. I was exceedingly well fixed in the inner angle of two large ſtreets cloſe to the angular point, one ſtreet lying North and South, and the other Eaſt and Weſt. The obſervation of a matter ſo very nice, is perhaps, as great a proof, a poſteriori, of the Earth moving in an elliptical orbit, as the publick was ever preſented with. Any aſtronomer who will be at the pains, and has leiſure to do it, will not be diſappointed of his purpoſe; but perhaps may find out ſomething curious with regard to the equable or unequable motion of the Earth on its Axis, for there are many things with reſpect to the going of the clock, which there is no room here to deſcribe. To return to Venus:

As the weather may prove unfavourable in ſome places, it were to be wiſhed that all men univerſally, who have any knowledge in theſe matters, would devote a little time to this one obſervation, eſpecially as it will be the only tranſit of Venus before the Sun which the preſent generation of men will ever have in their power to obſerve. If we ſhall be ſo happy as to get good obſervations from a great number of places, and the more the better; for every one knows, who is converſant in theſe matters, that many obſervations, greatly help to correct each other in finding out the truth: then may we depend upon it, that we ſhall be able correctly to aſcertain the quantity of the Sun's parallax; the conſequence of which will be, that we ſhall moſt certainly know its magnitude and diſtance, the magnitudes and diſtances of every planet in our ſolar ſyſtem, have a ſolid foundation of improvement in the more nice matters of aſtronomy for the uſe of navigation, and particularly in a moſt correct theory of the Sun, Moon and Venus.

As the motion of Venus is ſo wonderfully well adapted for this great purpoſe, not only in its exquiſite regularity and conſtancy, but in preciſe quantity, and numberleſs other circumſtances; inſomuch that it alone can benefit men in this great ſecret; it is therefore hoped that it will be accordingly attended to; and that in ſuch proportion, as the conſequence of the ſubject deſerves. Certainly it is as well adapted for determining the Sun's diſtance, as all other aſtronomical obſervations put together for determining the Moon; which we have beforehand ſhewn to be (within certain very ſmall limits) moſt truly known. It may be worth notice that the preſent tranſit will happen nearly in the oppoſite part of the Moon's node, to that of the tranſit in 1761.

FINIS.

| | | | | | | H. | M. | S. |
|---|---|---|---|---|---|---|---|---|
| Stockholm, | Lat. N. | 59 | 20 | 00 | Long Eaſt from Greenwich | 1 | 11 | 50 |
| Upſal | | 59 | 51 | 50 | | 1 | 10 | 10 |
| Abo | | 60 | 40 | 00 | | 1 | 28 | 17 |
| Hernoſand | | 62 | 30 | 00 | | 1 | 11 | 12 |
| Tornea | | 65 | 50 | 50 | | 1 | 36 | 28 |

| | | M. | S. |
|---|---|---|---|
| Sun's Semi Diameter in preceding Calculation | 15 | 45 | 6 |
| Venus's Semi Diameter | 00 | 28 | 6 |

| | H. | M. | S. |
|---|---|---|---|
| Geocentric Duration | 6 | 24 | 22 |

* * *

## E R R A T A.

Page 8. Line 11. for *caſe*, read *eaſe*.
10. laſt line, for *contrarirum*, read *contrarium*.
11. line 25. from the vertax, add, *when inverted*.
12. line 5. for *toutch*, read *touch*.